

**THE EFFECT OF SKATE BLADE RADIUS OF CONTOUR AND RADIUS OF
HOLLOW ON SKATING PERFORMANCE IN MALE ICE HOCKEY PLAYERS**

Andrew McKenzie, B.Sc. Kin.

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Under the supervision of Dr. Kelly Lockwood, Ph.D.

Faculty of Applied Health Sciences, Brock University

St. Catharines, Ontario

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Abstract

The primary purpose of this study was to investigate the effect of skate blade shape on skating performance. A secondary purpose was to evaluate if a change in hollow shape can create additional effects on skating performance. Thirty-seven male ice hockey players (age=18 years, $SD=3.4$) participated. The intervention consisted of four sharpening trials assessed using three on-ice tests. Participant feedback was also assessed using a Likert scale questionnaire. Statistical analysis included within-subject repeated measures MANOVA of trial by skating variables ($p \leq 0.05$). Results revealed Contour 1 enhanced performance compared to baseline on six variables at varsity level and five variables at midget level. Contour 1 enhanced performance compared to Contour 2 on six variables at the varsity and midget levels. Contour 1 also scored highest on the feedback questionnaire. Findings of this study indicate that contouring is a necessary practice to achieve optimal skating performance.

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List of Abbreviations

ROH: Radius of Hollow

ROC: Radius of Contour

BFD: Blademaster Form Dressing

SP: Skating Performance

ACC: Acceleration

B: Backwards

AG: Agility

LS: Linear Speed

OV: Overall Performance

ACC ISO: Acceleration Isolation

LS ISO: Linear Speed Isolation

AG ISO: Agility Isolation

rpm: Revolutions Per Minute

INT: Intervention Group

CON: Control Group

CHAPTER I: INTRODUCTION

The game of ice hockey requires players to be physically conditioned, technically astute and mentally cognizant of intangibles, such as game sense and sport instinct. What allows these attributes to be translated to game play is the player's interaction with the ice. Although skating is the fundamental skill, attention to the equipment and the process that facilitates effective blade-ice interaction is critical. Skate sharpening is accepted as a necessary process that can facilitate skating performance. However, there is limited knowledge into how skate sharpening can be used as a performance-enhancing tool. Broadbent (1983; 1985; 1988) has provided a theoretical understanding of how the geometry of the skate blade contributes to skating performance; however, empirical evidence quantifying the translation of skate blade geometry to the on-ice performance and the demands of the game is lacking.

The geometry of a skate blade can be defined by four skate sharpening characteristics: radius of contour (ROC), pitch, radius of hollow (ROH), and levelness of edges. The theoretical framework presented by Broadbent (1983; 1985; 1988) describes how the isolated skate sharpening characteristics can influence select aspects of skating performance.

The ROC, also known as the “rocker” or the profile of the blade, describes the lengthwise curvature of the skate blade (Figure 1) and determines how much blade is in contact with the ice (Broadbent, 1988). In theory, a longer radius of contour provides for greater contact of the skate blade with the ice, which should enhance speed. Alternatively, a shorter contour provides for less contact of the skate blade and ice

surface, which should enhance agility. Previous research has investigated the effects of ROC on selected skating skills. Results indicated that isolated, single contours do not significantly affect stopping (Gagnon & Dore, 1983) nor agility and speed performance (Hillman & Eldridge, 2003). Further investigation into single contours has found that a ROC adjusted for the mass of a skater significantly decreased aerobic fatigue in comparison to the ROC they were skating on prior to the intervention (Lockwood & Winchester, 2003).

The pitch describes the anterior or posterior lie of the skate blade. Pitch is created by moving the apex, defined as the highest point on the blade, either anterior or posterior along the length of the blade relative to blade centre (Figure 2). Moving the apex anterior along the blade creates a backwards pitch and moving the apex posterior along the blade creates a forward pitch.

The radius of hollow (Figure 3) is defined as the concave impression shaped into the running surface of the skate blade (Broadbent, 1983) which creates medial and lateral edges on the bottom of the skate blade. In theory, a deeper ROH provides for a greater bite angle and enhances grip. Conversely, a shallower ROH provides for a smaller bite angle and enhances glide (Broadbent, 1988). Research has determined that deeper hollows significantly reduce stopping distance and time (Gagnon & Dore, 1983; Winchester & Lockwood, 2006) but extremely deep hollows can significantly inhibit agility performance (Federlof & Redmond, 2010). Winchester & Lockwood (2006) provided practical information for the effect of hollow depth on acceleration performance. Feedback from the participants indicated that hollows that were too deep

made their skates feel like they were “sticking to the ice”, and hollows too shallow caused their skates to feel as though they were “spinning their tires”.

An alteration to ROH shape is a flat-bottomed hollow (Blademaster, 2009b), with edges similar to a conventional ROH and a flat portion between the edges. The flat-bottomed hollow was developed in an attempt to provide bite angles to penetrate into the ice and at the same time allowing for the capacity to glide across the ice. Currently, there is no empirical evidence to support the effect of a flat-bottomed hollow on skating performance.

Levelness of edges is defined as having the medial and lateral edges of the skate level to one another (Figure 4). Broadbent (1985) states that, it is imperative that the medial and lateral edges are the same height and any deviation from this will change how the skate blade interacts with the ice. Lockwood and Frost (2009) suggested that uneven edges increase injury risk of skaters by placing strain on ligaments, tendons and muscles not normally associated with skating.

Understanding how to manipulate skate blade geometry to optimize skating ability and address the various demands of ice hockey is a complex question that has yet to be comprehensively addressed. If ice hockey were a game of pure speed, then long contours would be most appropriate; conversely, if ice hockey were a game of pure agility, then short contours would be most appropriate. Hockey is unique in that it demands both speed and agility performance. In an effort to sufficiently address the performance demands of the game, skate blades possessing more than one contour have been developed, and referred to as, double contours. A relatively short contour is ground

onto the front of the blade to potentially enhance agility performance and a longer contour on the back of the blade to potentially enhance speed performance. Double contours are based on the assumption that longer contours increase the length of blade ice contact and therefore increase speed, whereas shorter contours decrease the length of blade ice contact and therefore enhance agility performance.

A preliminary investigation (McKenzie & Lockwood, unpublished) contrasted the performance effects of single versus double contours. Preliminary results suggested that a double contour has the potential to provide some performance advantages beyond the traditional single contour. However, the two contours create a distinct tipping point. Recent developments have attempted to eliminate the distinct tipping point by blending the two contours with a flat transition section, resulting in a triple contour. Currently there is no empirical evidence investigating the effects of triple contours on skating performance.

Therefore, the purpose of this study was to examine the effect of the shape of the blade, or ROC on selected on-ice skating performance variables. A secondary purpose was to examine if a change in shape of the radius of hollow (ROH) will create an additional effect on select on-ice skating performance variables. The results of the study have the potential to provide coaches, parents and players with empirical knowledge and education to guide best practices in skate sharpening.

CHAPTER II: REVIEW OF LITERATURE

Research investigating the effect of ice hockey equipment on a player's performance has focused predominantly on injury prevention through the development of protective gear, such as helmets (Spry, Pearsall & Hoshizaki, 2000), face shields (Lemair & Pearsall, 2007), and mouth guards (Takeda Ishigami, Shintaro, Nakajima, Shimada & Regner, 2004). However, hockey equipment not only provides protection against injury, it has the potential to facilitate performance. Innovations in hockey skate blades, such as design (t'-blade, 2011), temperature changes (Thermablades, 2011), composition (Whittom, Desmeules-Roy, Bouchard & Comtois, 2009), and sharpening (Gagnon & Dore, 1983; Hillman & Eldridge, 2003; Morrison, Pearsall, Turcotte, Lockwood & Montgomery, 2005; Federlof, Mills & Nigg, 2008; Federlof & Redmond, 2010; Federlof & Nigg, 2012) have been developed to aid player performance.

2.1 Composition of the Skate Blade

Standard skate blades, referred to as blade runners are made from stainless steel with a carbon-containing coating (Horkheimer, 2007). Stainless steel skate blades have been used since the 18th century due to the strength, malleability and availability of materials and are still used by the majority of hockey players today. Developments in skate blade materials have attempted to enhance performance by using metals other than stainless steel or by blending steel with other metals. For example, a titanium alloy has been found to produce a 2-5% increase in skating speed compared to standard stainless steel blades (Whittom, et al, 2009).

2.2 Dimensions of the Skate Blade

The early work by Broadbent (1983; 1985; 1988) has geometrically defined the characteristics of the skate blade. The skate blade consists of three basic dimensions: length, width and height. Blade length is defined as the distance from the back of the blade to the front and is proportional to skate size. Blade width is defined as the distance between the two sides of the skate blade and can vary from 2.29 to 3.05mm, depending on manufacturer. Blade height is defined as the distance from the bottom of the skate blade to the point where the blade inserts into the blade holder and is usually 16.5mm for new blades, but will vary by brand and will decrease as they are sharpened.

2.3 Skate Sharpening Characteristics

When a skate blade is sharpened, the dimensions as defined above can be altered. Changing the dimensions of the skate blade produces four characteristics of skate sharpening: radius of contour (ROC), pitch, radius of hollow (ROH), and levelness of edges (Figures 1-4). The ROC, also known as the “rocker” or the profile of the blade, describes the lengthwise curvature of the skate blade (Figure 1). The ROC determines how much blade is in contact with the ice (Broadbent, 1988). Longer contours increase blade-ice contact and are proposed to enhance speed; conversely, shorter contours decrease blade-ice contact are proposed the enhance agility capabilities.

The pitch describes the anterior or posterior lie of the skate blade. The pitch is created by moving the apex, defined as the highest point on the blade, either forward or back along the length of the blade relative to blade centre (Figure 2). The location of the apex on the skate blade is also referred to as pitch centre and changes the balance point on the blade (Broadbent, 1988).

The radius of hollow (ROH) is defined as the concave impression formed into the running surface of the skate blade (Broadbent, 1983)(Figure 3), creating medial and lateral edges on the bottom of the skate blade. These edges create a bite angle into the ice, described as the angle of penetration into the ice of the blade edges. The shallower the ROH, the lesser the bite angle will be into the ice. Having a shallower ROH is theorized to improve the glide and velocity of a skater, whereas a deeper ROH is theorized to enhance agility, along with stopping and starting abilities of skaters (Broadbent, 1988).

Levelness of edges is defined as having the medial and lateral edges of the skate level to one another (Figure 4). Broadbent (1985) states that it is imperative that the medial and lateral edges are the same height and any deviation from this will change how the skate blade interacts with the ice. Unleveled edges will change the angle at which the blade cuts into the ice and may not provide skaters with enough penetration into the ice for agility and turning. A generally acceptable range of error for levelness of edges is $1/1000^{\text{th}}$ of an inch. This means there can be $1/1000^{\text{th}}$ of an inch difference in height of the edges. Lockwood and Frost (2009) suggest that uneven edges can increase the probability of injury considerably by placing strain on joints, ligaments and muscles that are not normally associated with skating or over-stress the skating muscles.

2.4 Evolution of Skate Sharpening

The process of skate blade sharpening was traditionally performed by manually running a smooth stone lengthwise along the side of the blade to remove any rust or burrs (Brown, 1959). The development of mechanized skate sharpening machines in 1946 allowed

these characteristics to be altered by a sharpening technician (Wissota Manufacturing Company, 1996).

2.4.1 Creating a Contour

Mechanized skate sharpening machines possess a grinding stone spinning at high speeds (revolutions per minute) that is used to manipulate the lengthwise shape of a skate blade. The skate boot is secured in a holder that positions the skate blade parallel to the surface of the machine and the orientation of the grinding stone is perpendicular relative to the skate blade. When the bottom of the skate blade is run across the surface of the grinding stone in this position, a sufficient amount of blade is shaped in order to change the lengthwise curvature of the skate blade. Grinding off more blade from either the front or back of the blade also alters the pivot point and thus the pitch of the blade. Previous technology required the technician to take numerous measurements during this process to ensure the correct shape of the blade. Recent developments have created machines with a template bar system that can be fastened to the machine, which requires fewer measurements by the technician in order to reduce variability during contouring (Blademaster, 2009a).

2.4.2 Creating a Hollow

These same mechanized devices can also create a hollow on the bottom of a skate blade, with the orientation of the grinding stone parallel to the skate blade. When the grinding stone is in this position, a radius arm consisting of a steel rod fastened to the sides of the sharpening machine pivots around a grinding stone. Attached to the radius arm is a diamond point used to create a convex shape on the edge of the grinding stone while spinning. The process referred to as “dressing” the stone establishes the shape and size of the

ROH. Sliding the bottom of the skate blade across the grinding stone while spinning translates the shape on the stone to the bottom of the blade, creating a concave impression on the bottom of the skate blade. In order to create level edges on the hollow, the skate blade needs to be exactly parallel to the grinding stone.

Further evolution in skate sharpening technology has led to automated skate sharpening machines. Automated machines, under computer control are capable of dressing the stone as well as the interaction of the skate blade and grinding stone and could reduce the variability between sharpenings compared to manual machines operated human technicians.

Recent developments in skate sharpening technology have introduced a change to the geometric shape of the hollow on a skate blade. Instead of the circular arc seen in the conventional hollow, a combination of a flat surface between the medial and lateral edges has been created. This technology allows the technician to change the depth of the hollow without altering the bite angle into the ice (Blademaster, 2009b). Research investigating the efficacy of the design change is currently unavailable.

2.5 Skate Sharpening Research

Mechanical models have been developed to simulate the effect of skate sharpening on skating performance (Gagnon & Dore, 1983; Federlof & Redmond, 2010). Research has also utilized human models with the intent of providing a direct translation to in-game performance and to evaluate the impact of skate sharpening characteristics on physiological (Hillman & Eldridge, 2003; Morrison, et al, 2005; Lockwood & Winchester, 2003), biomechanical (Winchester & Lockwood, 2006) and kinematic

(Hillman & Eldridge, 2003; Federlof & Redmond, 2010; McKenzie & Lockwood, unpublished) measures of skating performance.

2.5.1 Skate Sharpening & Skating Physiology

Few studies have investigated the physiological impact of skate sharpening characteristics on skating performance. Initial results have shown that the ROC and ROH have the potential to influence the physiology of skating. Investigation into the impact of ROC on oxygen consumption found that a ROC adjusted for body weight allowed players to skate longer with less fatigue on an aerobic endurance skating test compared to contours based on the players' choice (Lockwood & Winchester, 2003). This indicates that players may not be skating on a contour that is appropriate for their anatomical configuration.

Hillman and Eldridge (2003) determined that shallower hollows lead to less lactic acid accumulation on an aerobic skating test. However, the same results are not found on a skating treadmill (Morrison, et al, 2005). No difference in oxygen consumption was seen between hollows of 6.35mm (1/4"), 12.7mm (1/2"), and 19.05mm (3/4"). As this test was performed on a synthetic surface, the blade-ice interaction is not the same as a real ice surface, so the results may not translate to on-ice performance. Despite results indicating that the ROH can influence aerobic performance, Winchester and Lockwood (2006) determined that ROH provided no difference in anaerobic performance on a Reed Repeat Skate (RRS) test. Hollows of 6.35mm, 12.7mm, and 19.05mm were investigated.

2.5.2 Skate Sharpening & Performance

Gagnon and Dore (1983) provided introductory research investigating the isolated effect of ROC on stopping performance. Measurements were taken with a stopping sled to provide a consistent stopping force and angle of the skate relative to the ice. It was determined that contours of 2.13m (7') and 3.96m (13') provided no difference in stopping distance and time. Further investigation into the effect of ROC on skating performance found no difference between contours of 2.74m (9') and 3.05m (10') on agility and speed (Hillman & Eldridge, 2003). Ice hockey is a unique sport that demands both speed and agility performance. If ice hockey were a game of pure speed, then long contours would be most appropriate; conversely, if ice hockey were a game of pure agility, then short contours would be most appropriate. The skate blades should address the both speed and agility performance.

Gagnon and Dore (1983) used the same stopping sled to investigate the isolated effect of ROH on stopping performance and determined deeper hollows resulted in a significantly shorter stopping distance and time. A 12.70mm hollow produced a significantly shorter stopping distance and time compared to a 38.10mm (1 1/2") hollow. The effect of ROH on stopping performance has also been investigated using human models. Winchester & Lockwood (unpublished) determined that a 6.35mm hollow resulted in a significantly shorter stopping distance and time compared to hollows of 12.70mm and 19.05mm. Further, practical information in the review stated that hollows which were too deep made their skates feel like they were sticking to the ice, and hollows which were too shallow caused their skates to feel as though they were "spinning their tires". Results from both mechanical (Gagnon & Dore, 1983) and human models

(Winchester & Lockwood, 2006) are consistent in revealing that deeper hollows significantly improve stopping performance. The work of Federlof and Redmond (2010) suggested there are limitations to hollow depth as hollows that are extremely deep can significantly reduce agility performance. A ROH of 3.18mm (1/8") resulted in significantly longer run times on an agility course compared to ROH of 9.5mm (3/8"), 15.9mm (5/8") and 22.3mm (7/8").

Previous research has provided unclear evidence on how skate blade geometry can be optimized for skating performance. Innovations in skate blade shape have created blades that possess both a long and a short contour, referred to as double contours. According to theory (Broadbent, 1988), a double contour with a shorter contour on the front half of the blade and longer contour on the back half of the blade would optimize both agility and speed. Preliminary investigation determined that these double contours have the potential to enhance agility performance in midget skaters (McKenzie & Lockwood, unpublished). However, the two different contours on a double contour can create a distinct pivot point where they meet, so further developments in ice hockey have created double contours with a portion of the blade flat, referred to as 'triple contours'. The flat section acts as a transition space between the two different contours and if the assumption that a flat blade increases blade-ice contact and accentuates speed performance (Broadbent, 1988), the flat section on a contour could provide further enhancements to speed performance. It is unknown if the triple contours can adequately address the diverse demands of ice hockey.

A development in ROH shape has created a flat-bottomed hollow (Blademaster, 2009b). A conventional ROH shape is semi-circular, where as a flat-bottomed hollow has

edges similar to a conventional ROH and a flat portion between the edges. The flat-bottomed hollow was developed in an attempt to provide enough large bite angles to penetrate into the ice and at the same time allowing for the capacity to glide across the ice.

The research described above present's evidence of the isolated effects of ROC and ROH on various measures of skating performance. Also presented are developments to skate blades with triple contours and flat-bottomed hollows, but the efficacy of these designs has yet to be investigated. It is unknown if these changes will be able to adequately address the diverse demands of ice hockey.

2.6 Purpose of Study

The primary purpose of this study was to examine the effect of the shape of the blade or radius of contour (ROC) on select on-ice skating performance variables. The secondary purpose was to examine if a change in shape of the radius of hollow (ROH) creates an additional effect on select on-ice skating performance variables.

The first null hypothesis states there is no significant difference in the skating performance (SP) variables between baseline and two contour interventions, $SP_{\text{CONTOUR 1}}$ and $SP_{\text{CONTOUR 2}}$.

$$H_1 = SP_{\text{BASELINE}} = SP_{\text{CONTOUR 1}} = SP_{\text{CONTOUR 2}}$$

The second null hypothesis states there is no significant difference in skating performance variables between optimal contour and optimal contour with a change in hollow shape.

$$H_2 = SP_{\text{OPTIMAL ROC}} = SP_{\text{OPTIMAL ROC w/BFD}}$$

2.7 Significance of Study

This study provided insight into the practice of skate sharpening specifically with regard to contouring and how to optimize skate blades to enhance skating performance. It also provided evidence to support industrial development to further investigate the effects of further changes to skate blade shape.

2.8 Limitations

- a) A heterogeneous intervention group was comprised of sixteen varsity and eight midget skaters.
- b) The control group was limited to midget level players only.
- c) Linear speed section in the Combination test may not have permitted a maximal skating effort.
- d) The familiarization period was limited to 10 minutes.
- e) Equipment used for testing restricted participants from carrying a stick during completion of performance tests.
- f) Potential effect of foot dominance on performance was not considered.

CHAPTER III: METHODS

3.1 Participants

Thirty-seven male ice hockey players were recruited to participate. Participants were limited to players in the positions of forward (n=20) and defense (n=17), who were injury free and currently participating at a high level of competitive hockey. Twenty-four participants (forward = 13; defense = 11) served as the intervention group receiving both the contour and hollow intervention (Varsity (VAR)=16; Midget (MID)=8). Thirteen midget players (forward = 7; defense = 6) served as controls (C-MID) for comparison to the midget players in the intervention group. Participants completed informed consent prior to participating in the study (Appendix A). The proposed study received ethical approval from the Brock University Research Ethics Board (File # 10-085).

3.2 Experimental Design

The study design was a randomized triple-blind control trial. Players' names, skates and blades were coded to ensure confidentiality and blinding. The researcher performing the skate sharpening, the researchers conducting the on-ice assessments and the athletes participating in the study were not informed of the characteristics of skate sharpening that each participant was using during the skating tests. Participants in the intervention group were required to complete four trials, each with different skate sharpening characteristics. Skating performance was measured using the same on-ice tests at every trial. Trials were one hour in duration, with a minimum 24 hours rest between trials. The study was conducted during the hockey season, so participants

maintained their normal practice, game and training schedules for the duration of the study.

The control group was matched for level of play, gender, age and position to the midget players in the intervention group. The control group completed the same on-ice testing as the intervention group at two time points, with at least 24 hours rest between testing sessions and without any of the sharpening interventions.

3.3 Sharpening Interventions

One skilled technician performed the sharpening of all skate blades prior to each testing session using a Blademaster Skate Sharpener™ (Guspro Inc., Chatham, ON). ROC was applied to the blades using a Blademaster Single Point Custom Contouring System (Guspro Inc., Chatham, ON) and the precision of the contours was verified using Blademaster Contour Radius Bars (Guspro Inc., Chatham, ON). ROH and Blademaster Form Dressing (BFD) was applied to the grinding stone using a Blademaster Multi Purpose Form Dresser (Guspro, Inc., Chatham, ON). To verify the accuracy and precision of the ROH, measurements were taken at three distinct points on the blade using a Hollow Depth Indicator™ (HDI) (Edge Specialties Inc., Alexandria, MN). The levelness of edges was determined using a Quick Square (Maximum Edge™, Windsor, ON) following each sharpening.

Trial 1 required participants to skate on their current skate blades without any sharpening intervention. Trials 2 and 3 consisted of the randomized contour interventions. A simple randomization method was used to determine the order of contour intervention for each participant. ROH was held constant at 1.27cm, tolerance for

the levelness of edges was set at 1/1000 inch of level, and pitch was set to +1. Trial 4 was the ROH intervention. The ROC that elicited the greatest positive difference to performance was applied to the skate blades with a flat-bottomed hollow. A positive difference in performance is considered an enhancement to performance. The corresponding flat-bottomed hollow to the 1.27cm ROH is a BFD x6. Pitch and levelness of edges remained constant as previously described.

Trial 1. Baseline ROC & ROH: Skaters completed this testing session on their current skate blades and skate sharpening characteristics. Measurements of existing ROC, ROH, pitch and levelness of edges of the intervention group were recorded to establish a baseline.

Trial 2. Contour 1: 2.74m – 5.08cm – 3.05m ROC: Skaters completed the on-ice testing on a moderate triple contour. In theory, a contour with a relatively short and long contour will adequately address the many demands of ice hockey. A triple contour, comprised of a 2.74m (9ft) contour from pitch centre forward, a 3.05m (10ft) contour from pitch centre back, and a 5.08cm (2in) flat section between the contours was investigated to determine if triple contours could enhance both agility and speed performance.

Trial 3. Contour 2: 2.13m – 5.08cm – 3.96m ROC: Skaters completed the on-ice testing on a more radical triple contour compared to Contour 1. A triple contour, comprised of a 2.13m (7ft) contour from pitch centre forward, a 3.96m (13ft) contour from pitch centre back, and a 5.08cm (2in) flat section between the contours was investigated to determine if there are further enhancements to agility and speed performance with a more radical contour shape.

Trial 4. Optimal ROC w/ BFD x6: Skaters completed the on-ice testing with the contour they performed the fastest on from Trials 2 and 3 along with a BFD x6. The BFD x6 was used to determine if a flat-bottomed hollow shape could provide further enhancements to skating performance.

3.4 Testing Protocol

Participants were permitted a 10-minute familiarization period to become accustomed to the sharpening characteristics. Three skating tests were selected to assess the effect of skate sharpening characteristics on skating performance variables. The order of the tests was held constant across all four trials. The time taken to complete the tests was recorded using a Tag Heuer™ HL610 photoelectric timing system (la Chaux-De-Fonds, Switzerland). The time to complete each test was used as the measure of skating performance. Verbal encouragement was provided to all players during testing.

The order of tests was consistent for all participants. The work to rest ratio was approximately 1:20 minutes. When necessary, drills were moved to a new location on the ice or ice resurfacing was completed to provide optimal conditions. Ice conditions that might have affected skaters' performance were recorded in the field notes. Ice temperature was recorded on an hourly basis to provide further understanding of the variables affecting blade-ice interaction. Average ice temperature was -5.0°C, ranging from -5.4°C to -4.8°C.

3.4.1 Linear Speed Test

The Linear Speed Test was a 38m on-ice sprint (Figure 5). Skaters started in a two-foot stance, facing perpendicular to the direction of travel with one hand on the end

boards. Participants skated 38m from the goal line into the far end zone. The skater's linear speed isolation (LS ISO) and acceleration isolation (ACC ISO) were measured via photoelectric timing lights placed on the near and far blue line.

3.4.2 Combination Test

The Combination Test is a continuous skating test consisting of four sections: acceleration (ACC), backwards (BACK), agility (AG) and linear speed (LS) (Figure 6). Skaters started in a two-foot stance perpendicular to the direction of travel, with one hand on the end boards. Players began at their own discretion, skating from the goal line and pivoting backwards at the blue line (ACC). The backwards section was 18m. Players pivoted forwards after 18m and continued into the AG section. The agility portion (AG) consisted of a five-pylon agility pattern (Figure 7) that led the skaters into the LS section of the test. The LS section covered a distance of 38m, from the end of the AG section to the same goal line where the test was started. The time to complete the Combination Test was used as the overall (OV) performance measure, and the participant's fastest time on the Combination Test determined their optimal ROC.

3.4.3 Agility Test

The Agility Test was a repeat of the AG section of the Combination Test (Figure 7). The skaters started on the neutral zone faceoff dot in a two-foot stance, facing perpendicular to the direction of travel and completed the same five-pylon agility pattern as the Combination Test. The time to complete the Agility Test was used as the performance measure for agility isolation (AG ISO).

3.5 Participant Feedback

Following each intervention trial, participants were asked to complete a 6-question Likert scale (1 to 5) survey providing feedback on their perceived performance and comfort comparisons between the current trial and their normal sharpening. Survey questions included ratings on speed, agility, forward skating and backward skating (Appendix B).

3.6 Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 19.0 (IBM, Chicago, IL). Descriptive statistics, including mean (M) and standard deviation (SD), were calculated for all performance variables. Frequencies of responses to each question and total score on the feedback questionnaire was calculated for each participant. A one-way ANOVA of group by performance measures was used to determine any significant differences between the control group and the midget players in the intervention group at baseline. A within subject repeated measures ANOVA of trial by performance measures were used to determine if performance time changed for the control group over the two testing sessions. A series of Pearson Product Moment correlations were performed to assess the relationship between agility and agility isolation run times, acceleration and acceleration isolation times as well as, linear speed and linear speed isolation run times on each trial for playing levels independently. A within subject repeated measures MANOVA of trial by skating performance variable was conducted to determine significant differences in performance between intervention trials. Playing level, position and shooting hand were included as factors to determine if these variables had an effect on performance times. If significant differences were found, a *post-hoc* Least Squares Difference (LSD) significance test was performed to determine

where the significant differences were located. A within subject repeated measures MANOVA of trial by performance measures was used to determine significant differences between the optimal ROC and optimal ROC with BFD x6. If significant differences were found, a *post-hoc* Least Squares Difference (LSD) significance test was performed to determine where the significant differences were located. A Kruskal-Wallis Test was conducted to determine significant differences between total scores on the feedback questionnaire. An alpha level of $p \leq 0.05$ was set to indicate statistical significance for all analyses.

CHAPTER IV: RESULTS

4.1 Descriptives

Age, height and mass of the intervention and control group can be found in Table 1. The varsity group was significantly taller and heavier than the midget participants in the intervention group and the control group. There was no significant difference in height or mass between the midget participants in the intervention group and the midget controls. The control group was matched by age and competition level to the midget players in the intervention group (Table 1). There were more forwards than defensemen ($n=20$ forward; $n=17$ defense), and just over half of the participants shot left-handed ($n=19$ left; $n=18$ right) (Table 2).

Prior to on-ice testing, existing contours were measured and recorded for all participants (Table 3). Baseline contours were single contours ranging from 2.44 to 3.35m (Table 3). The most frequent contour used by this cohort was a 2.74m contour (78%). The ROH measurements indicated that all participants were skating on a conventional concave hollow at baseline (Table 3). Sixty-eight percent of participants were skating on a 1.27cm hollow ($n=25$) at baseline.

A comparison of the intervention and control groups on the baseline measures revealed no significant difference in age, height and mass of the midget players. Furthermore, no significant difference was found between the performance times at baseline for the midget control and intervention groups ($F[8,12]=1.131$, $p=.409$) (Table 4). In addition, the control group's performance times did not change significantly between the two testing sessions (Table 4) approximately eight weeks apart

($F[8,5]=1.695, p=.291$). This suggests that time was not a factor in any performance differences nor was there a learning curve for the tests.

4.2 Correlations

Pearson Product Moment correlations revealed significant correlations between the times for the isolation and combination test for acceleration ($r=.54, p=.000$), linear speed ($r=.69, p=.000$) and agility ($r=.57, p=.000$), for the varsity performance times. Midget performance times revealed significant correlations between the times for the isolation and combination test for acceleration ($r=.97, p=.000$), linear speed ($r=.86, p=.000$) and agility ($r=.90, p=.000$). These correlations indicate the tests in combination and in isolation provided consistent times for the varsity and midget skaters.

4.3 Sharpening Interventions

A within subject repeated measures MANOVA of three trials (Trial 1, Trial 2, Trial 3) by 8 performance variables (ACC, ACC ISO, BACK, AG, AG ISO, LS, LS ISO, OV) was completed. The analysis revealed significant differences between Trial #1, Trial #2 and Trial #3 ($F[16,8]=7.790, p=.003$) on the skating performance measures for the entire intervention group ($n=24$). When competition level was included as a factor, a significant difference was revealed between varsity and midget levels within the intervention group at baseline ($F[8,15]=9.581, p=.000$) on BACK ($p=.000$), AG ($p=.004$), AG ISO ($p=.042$), LS ($p=.001$), LS ISO ($p=.003$) and OV ($p=.000$). Position and shooting hand were included as factors, and revealed that position ($F[8,5]=0.513, p=.809$) and shooting hand ($F[8,5]=0.909, p=.570$) had no significant effect on any of the performance variables for the intervention group, or for each level independently, indicating that these

characteristics had no individual effects on the results. Furthermore, there was no interaction between trial and position ($F[16,36]=0.987, p=.490$), trial and shooting hand ($F[16,36]=1.674, p=.099$), or trial by position and shooting hand ($F[16,36]=0.828, p=.648$) for the entire intervention group or each playing level independently.

4.3.1 Trial 1: Baseline vs Trial 2: Contour 1 (2.74m-5.08cm-3.05m)

The varsity results indicated that Contour 1 enhanced performance on six variables compared to baseline (ACC, BACK, AG, OV, AG ISO, LS ISO) with performance on three of the six variables (AG, AG ISO, $p=.000$; LS ISO, $p=.000$) (Table 6). Furthermore, Contour 1 decreased OV time by an average of 1.47% and AG section time by an average of 2.60% compared to baseline. These results indicate that the moderate triple contour can significantly enhance agility, agility isolation, and linear speed isolation performance compared to single contours in the varsity sub-set. Further, acceleration, backwards, and overall performance measures were enhanced, despite not reaching statistical significance, compared to single contours in the varsity sub-set. In the midget sub-set, Contour 1 enhanced performance, but not significantly on five variables compared to baseline (BACK, AG, AG ISO, LS, OV) (Table 7). Similar to the varsity level, Contour 1 decreased OV time by an average of 0.75%, AG ISO time by 1.57% and BACK section time by 4.53% compared to baseline. These results indicated that at the midget level, a moderate triple contour has the potential to enhance backwards, agility (both in combination and isolation), linear speed, and overall performance compared to single contours. The pooled intervention data exhibited similar findings (Table 5). Contour 1 enhanced performance on six variables compared to baseline (ACC, BACK, AG, AG ISO, LS ISO, OV), reaching statistical significance on two of those variables

(AG ISO, $p=.000$; LS ISO, $p=.001$). Similar to the varsity and midget levels, OV time decreased by an average of 1.22%. The varsity, midget and pooled results taken together showed that a moderate triple contour can enhance acceleration, backwards, agility (in combination and isolation), linear speed isolation, and overall performance in comparison to single contours.

4.3.2 Trial 1: Baseline vs Trial 3: Contour 2 (2.13m-5.08cm-3.96m)

In comparison to baseline times, Contour 2 enhanced performance on two variables (BACK & LS ISO) at the varsity level (Table 6). Contour 2 significantly enhanced linear speed isolation performance ($p=.000$) and decreased backwards section time by an average of 1.31%. These results indicate that a radical triple contour was able to significantly enhance linear speed isolation performance at the varsity level compared to single contours.

The results for the midget players revealed that the Contour 2 enhanced performance on three variables (BACK, AG, AG ISO) compared to baseline (Table 7). Backwards section time decreased by an average of 2.26% and agility times by an average of 3.07% (AG: 2.21%; AG ISO: 3.93%). These results indicate that a radical triple contour has the potential to enhance backwards and agility performance (both in combination and in isolation) at the midget level compared to single contours. The pooled results revealed that Contour 2 enhanced performance on four variables compared to baseline (BACK, AG, AG ISO, LS ISO) (Table 5). Contour 2 decreased backwards section time by an average of 1.70%, agility isolation time by an average of 1.50%, and linear speed isolation time by an average of 1.21%. The varsity, midget and pooled results taken together demonstrate that a radical triple contour (Contour 2) has the

potential to enhance backwards, agility (both in combination and isolation) and linear speed isolation performance compared to single contours.

4.3.3 Trial 2: Contour 1 (2.74m-5.08cm-3.05m) vs Trial 3: Contour 2 (2.13m-5.08cm-3.96m)

A comparison of the triple contours to each other revealed the moderate triple contour provided a greater enhancement to skating performance compared to a radical triple contour (Table 6). At the varsity level, Contour 1 enhanced performance on six of the eight performance variables compared to Contour 2, with the difference reaching statistical significance on five variables (ACC, $p=.010$; ACC ISO, $p=.000$; AG, $p=.000$; AG ISO, $p=.000$; LS ISO, $p=.016$). Further, Contour 1 decreased OV time by an average of 1.98%. These results indicate that Contour 1 significantly enhanced acceleration (in combination and isolation), agility (in combination and isolation), and linear speed isolation performance compared to Contour 2 at the varsity level.

The midget level findings support the varsity results in that Contour 1 produced faster average times on six performance variables (ACC, ACC ISO, BACK, LS, LS ISO, OV) compared to Contour 2, although the differences did not reach statistical significance (Table 7). Contour 1 decreased ACC by an average of 2.74%, BACK by 2.37%, and OV by an average of 0.75% compared to Contour 2. The results indicate Contour 1 has the potential to enhance acceleration (in combination and isolation), backwards, linear speed (in combination and isolation), and overall performance compared to Contour 2 at the midget level. The pooled intervention data revealed that Contour 1 increased performance on all eight variables compared to Contour 2, reaching statistical significance on four variables (ACC, $p=.002$; ACC ISO, $p=.003$; AG ISO,

$p=.010$; LS ISO, $p=.004$) (Table 5). These results indicate Contour 1 significantly enhanced acceleration (in combination and isolation), agility isolation, and linear speed isolation performance compared to Contour 2. More importantly, the results showed that 63% of varsity ($n=10$) and 75% of midget ($n=6$) skaters performed better with Contour 1.

4.3.4 Trial 4

The MANOVA completed on the varsity sub-set revealed that the BFD intervention enhanced linear speed performance by an average of 1.13% compared to the conventional hollow (Table 8). However, the BFD intervention significantly hindered acceleration (ACC, $p=.002$; ACC ISO, $p=.040$), agility isolation ($p=.000$), and overall skating performance ($p=.007$) compared to the optimal contour with a conventional hollow. The optimal contour with a flat-bottomed hollow enhanced linear speed performance, but significantly inhibited acceleration and overall skating performance compared to a conventional hollow. This indicates that the change in hollow shape did not create an additional effect on skating performance compared to a conventional hollow at the varsity level.

The MANOVA completed on the midget sub-set revealed the BFD intervention enhanced agility performance compared to a conventional hollow by an average of 0.72% (Table 8). However, the BFD intervention significantly hindered two measures (ACC, $p=.007$; OV, $p=.008$). The optimal contour with a flat-bottomed hollow significantly inhibited acceleration and overall skating performance compared to the optimal contour conventional hollow. This indicates the change in hollow shape did not create an additional beneficial effect on skating performance compared to a conventional hollow at the midget level.

The MANOVA completed on the combined dataset indicated that the change in hollow shape did not enhance any variables of skating performance, and significantly inhibited three measures (ACC, BACK, OV) compared to performance on the conventional hollow ($p=.000$; $p=.003$; $p=.000$, respectively). These results indicated that the change in hollow shape significantly inhibited acceleration, backwards, and overall skating performance compared to a conventional hollow.

4.4 Participant Feedback

The results of the Kruskal-Wallis Test on the entire intervention data determined Contour 1 was scored significantly higher than Contour 2 ($p=.018$) and the BFD intervention ($p=.001$) (Table 9). There was no significant difference between Contour 2 and the BFD intervention. This indicated that Contour 1 was the most preferred intervention.

In summary, the results of contour intervention trials 1-3 rejected the first null hypothesis. Select skating skills performed on Contour 1 were significantly faster than the same skills performed during the baseline trial, representative of a single or manufactures contour. Furthermore, Contour 1 was also significantly better and preferred by the players in comparison to Contour 2. The results of the hollow intervention trial, trial 4, reject the second null hypothesis. Select skating skills performed on an optimal ROC with a flat-bottomed hollow were significantly slower than the same skills performed on an optimal ROC and a conventional hollow. Figures 8-13 illustrate trends seen in each group by trial.

CHAPTER V: DISCUSSION

Equipment developed for ice hockey has been designed with the intent of addressing specific demands of the game or enhancing the overall performance of the players. The blade-ice contact facilitated by the contour of the skate blade (ROC) has the potential to enhance skating performance, namely speed and agility. Relatively short contours decrease turning radius and are assumed to enhance agility performance, whereas longer contours increase blade-ice contact and are assumed to enhance speed performance. Traditionally, skate blades are manufactured with a single 9ft contour. Results of this study provided evidence to suggest that contouring is not a common practice; 100% of the participants were skating on a single contour at baseline, with 78% of these contours being representative of a traditional contour (9ft). Even though a comparison of a single contour to a double contour suggested that a single 9ft contour did not address agility or speed performance (McKenzie & Lockwood, unpublished), this knowledge has not been translated to practice.

In theory, it was proposed that skate blades with two contours have the potential to enhance both agility and speed performance. A double contour consists of a shorter contour being applied to the front half of the blade as skaters routinely shift their centre of gravity (CoG) forward when turning (Pearsall, Turcotte & Murphy, 2000). Conversely, a longer contour is applied to the back of the blade as skaters routinely shift their CoG onto the posterior portion of the blade when gliding (Pearsall, Turcotte & Murphy, 2000).

The results of a preliminary investigation (McKenzie & Lockwood, unpublished) suggested that a skate blade with a relatively short contour from pitch centre forward and

longer contour from pitch centre back was able to enhance agility performance, however did not sufficiently address speed performance in midget skaters. A possible explanation could be that the longer contour on the back of the blade did not increase blade-ice contact enough to enhance speed performance.

The current study investigated the effects of further increasing the length of the longer contour by including a flat transition section, resulting in a third contour. Design recommendations (Blademaster, 2009a) proposed that the flat portion was intended to act as a transition between the two contours as well as increase the length of the longer contour. The moderate triple contour (Contour 1) comprised of a 9ft ROC from pitch centre forward, a 10ft ROC from pitch centre back with a 2 inch transition at pitch centre significantly enhanced agility and speed performance in the varsity sub-set compared to a standard single contour. The flat portion further increased blade-ice contact compared to the 10ft contour on the posterior section of the double contour and could explain why speed performance was enhanced compared to the double contour. In all sub-sets, some differences in performance did not reach statistical significance, but the observed differences were large enough to have a notable effect on skating performance. For example, Contour 1 enhanced overall performance by an average of 1.47% compared to baseline in the varsity sub-set. On a test that covers approximately 110m, the 1.47% difference translates to 1.67m. In ice hockey, a 1.67m advantage will have a considerable effect in game play and performance. One reason why statistical significance was not reached was the large variance in the performance times in the varsity and midget sub-sets. Even though participants were selected from high levels of minor hockey, relative to

the majority of the hockey community, teams were comprised of skaters of varying skating abilities.

Comparing the performance effects between single contours, double contours and the triple contours, the moderate triple contour was able to sufficiently address the integrated skating demands of ice hockey in a test that represents the multiple skills of game play. The shape of the moderate triple contour was not drastically different from the single contours traditionally used by the players, however the inclusion of a flat section increased the amount of blade-ice contact and could have enhanced speed performance.

Theoretically, the assumption that shorter contours enhance agility and longer contours enhance speed performance would lead us to believe that the radical triple contour (Contour 2) used for the purpose of the study should enhance both speed and agility performance when compared to the moderate triple contour (Contour 1). The results revealed that Contour 2 enhanced backwards performance compared to standard single contours, but failed to further enhance skating performance compared to the moderate triple contour in both sub-sets. Although participants were provided with a 10-minute familiarization period prior to testing, the level of comfort could have contributed to the players' level of confidence in performing skating drills with maximal effort. This was reflected in slower performance times recorded while skating on Contour 2, as well as, significantly lower scores on the feedback questionnaire. The low questionnaire scores suggested that there might be a level of comfort or familiarization required to perform on radically contoured blades. Subjective feedback from the players suggested that a skater's perception of their blade-ice interaction also affected their skating

performance. Contour 1 provided the greatest performance differences and was also supported with the greatest comfort as confirmed by subjective data from the feedback questionnaire. As it was stated previously, Contour 1 was comprised of contours common to ice hockey, whereas Contour 2 was comprised of contours not common to the participants in this study (Table 3). It is likely that the participants had not previously experienced skating on 7ft or 13ft contour; therefore they were not familiar with the feel of the blades on the ice.

It was hypothesized that, the addition of a flat-bottomed hollow shape to the contour of choice, would result in an additional enhancement to skating performance. The outcome of the present study indicated that the flat-bottomed hollow shape did not create an additional effect on skating performance compared to the conventional hollow. Many of the participants commented that the flat-bottomed hollow caused their blades to feel too sharp, inhibiting glide while skating.

In conclusion, there are many physical and mental factors that can affect optimal athletic performance. In the sport of ice hockey, players can be physically conditioned and mechanically sound but if their point of interaction with the ice doesn't allow for these attributes to be displayed, then optimal skating performance could be compromised. A player's equipment, specifically skate blades and the way in which the blades are prepared for performance, plays a significant role in optimizing skating performance. The results of the current study provided evidence to suggest that contouring is a necessary process for optimal skating performance. Furthermore, insight into the performance effects of selected single, double and triple contours was quantified. These findings are relevant to players, coaches and parents at all levels and in support of the industry to

further advance their knowledge of the influence of skate sharpening characteristics on skating performance as translated to game play.

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Table 1. Participant demographics

Descriptive	Intervention			Control (n=13)
	Varsity (n=16)	Midget (n=8)	Total (n=24)	
Age (y)	22.1 (1.0)	15.9 (0.8)	20.0 (3.1)	15.2 (0.4)
Height (cm)	183.63 (6.90)*	179.50 (3.07)	182.25 (6.15)	175.69 (4.66)
Mass (kg)	86.42 (8.00)*	78.18 (5.36)	83.67 (8.11)	71.05 (5.60)
BMI (kg/m ²)	25.59 (1.21)	24.25 (1.18)	25.14 (1.34)	23.02 (1.61)

Data are mean (SD)

* Significantly greater than Midget and Control ($p<.05$)

Table 2. Participant descriptives

Descriptive	Frequency (n)	
	Intervention	Control
<u>Skate Brand</u>		
Bauer	17	10
Reebok	3	1
Graf	2	1
Easton	1	0
CCM	1	1
<u>Holder Brand</u>		
Tuuk	17	10
E-Pro	4	2
Cobra	2	1
Razor	1	0
<u>Position</u>		
Forward	13	7
Defense	11	6
<u>Shooting Hand</u>		
Left	13	6
Right	11	7
n=37		

Table 3. Sharpening descriptives

Descriptive	Frequency (n)	
	Intervention	Control
<u>ROC</u>		
<2.74m	3	2
2.74m	18	11
>2.74m	3	0
<u>ROH</u>		
≤0.95cm	6	3
1.27cm	16	9
≥1.59cm	2	1
<u>Levelness of Edges</u>		
Yes	13	6
No	11	7
n=37		

Table 4. Control vs midget intervention performance times

Measure	Intervention (n=8)	Control (n=13)	
	Baseline	Baseline I	Baseline II
Acceleration (s)	2.82 (.18)	2.96 (.14)	3.00 (.08)
Acceleration Isolation (s)	2.81 (.17)	2.90 (.11)	2.91 (.11)
Backwards (s)	2.65 (.27)	2.56 (.12)	2.62 (.12)
Agility (s)	8.58 (.71)	8.56 (.26)	8.68 (.39)
Agility Isolation (s)	8.93 (.64)	9.06 (.24)	9.13 (.33)
Linear Speed (s)	4.74 (.23)	4.79 (.19)	4.70 (.24)
Linear Speed Isolation (s)	5.05 (.18)	5.15 (.13)	5.15 (.19)
Overall (s)	18.79 (.73)	18.95 (.43)	19.00 (.61)

Data are mean (SD)

* $p < .05$

Table 5. Pooled skating performance times across contour trials

Measure	Baseline	Contour 1 (9'-2"-10')	Contour 2 (7'-2"-13')
Acceleration (s)	2.83 (.13)+	2.79 (.13)+	2.90 (.15)
Acceleration Isolation (s)	2.78 (.12)+	2.78 (.11)+	2.83 (.14)
Backwards (s)	2.41 (.24)	2.36 (.19)	2.37 (.24)
Agility (s)	8.26 (.54)	8.11 (.46)+	8.23 (.41)
Agility Isolation (s)	8.64 (.46)	8.27 (.54)*+	8.51 (.38)
Linear Speed (s)	4.52 (.27)	4.53 (.25)	4.91 (.29)
Linear Speed Isolation (s)	4.97 (.21)	4.84 (.25)*+	4.91 (.24)

Data are mean (SD) (n = 24)

* Significantly faster than Baseline ($p \leq .05$)

+ Significantly faster than Contour 2 (7'-2"-13') ($p \leq .05$)

Table 6. Varsity skating performance times across contour trials

Measure	Baseline	Contour 1 (9'-2"-10')	Contour 2 (7'-2"-13')
Acceleration (s)	2.84 (.10)	2.77 (.12)+	2.89 (.11)
Acceleration Isolation (s)	2.76 (.08)+	2.76 (.10)+	2.82 (.12)
Backwards (s)	2.29 (.10)	2.28 (.10)	2.26 (.10)
Agility (s)	8.10 (.36)	7.89 (.25)+	8.15 (.29)
Agility Isolation(s)	8.49 (.26)	8.02 (.24)*+	8.49 (.24)
Linear Speed (s)	4.41 (.21)	4.43 (.22)	4.42 (.22)
Linear Speed Isolation (s)	4.93 (.22)	4.73 (.16)*+	4.80 (.19)

Data are mean (SD) (n = 16)

* Significantly faster than Baseline ($p \leq .05$)

+ Significantly faster than Contour 2 (7'-2"-13') ($p \leq .05$)

Table 7. Midget skating performance times across contour trials

Measure	Baseline	Contour 1 (9'-2"-10')	Contour 2 (7'-2"-13')
Acceleration (s)	2.82 (.18)+	2.84 (.11)	2.92 (.20)
Acceleration Isolation (s)	2.81 (.10)	2.82 (.10)	2.86 (.18)
Backwards (s)	2.65 (.27)	2.53 (.23)	2.59 (.29)
Agility (s)	8.58 (.71)	8.56 (.48)	8.39 (.57)
Agility Isolation (s)	8.92 (.64)	8.78 (.64)	8.57 (.59)
Linear Speed (s)	4.74 (.23)	4.73 (.19)	4.79 (.28)
Linear Speed Isolation (s)	5.05 (.18)+	5.07 (.25)	5.13 (.16)

Data are mean (SD) (n = 8)

* Significantly faster than Baseline ($p \leq .05$)

+ Significantly faster than Contour 2 (7'-2"-13') ($p \leq .05$)

Table 8. Optimal ROC with conventional hollow and flat bottom performance times

Measure	Optimal ROC	Optimal ROC w/ BFD
Acceleration (s)	2.82 (.12)	2.94 (.12)*
Acceleration Isolation (s)	2.81 (.11)	2.81 (.17)
Backwards (s)	2.44 (.23)	2.58 (.31)*
Agility (s)	8.25 (.52)	8.33 (.48)
Agility Isolation (s)	8.52 (.64)	8.64 (.42)
Linear Speed (s)	4.62 (.23)	4.71 (.47)
Linear Speed Isolation (s)	4.98 (.25)	5.00 (.24)
Overall (s)	18.03 (.90)	18.56 (1.09)*

Data are mean (SD) (n = 24)

* Significant difference from Optimal ROC ($p < 0.05$)

Table 9. Average total score on participant questionnaire

Contour	Average total score
9'-2''-10'	20.04 (4.69) *+
7'-2''-13'	17.04 (4.50)
BFD	15.58 (3.80)

Data are mean (SD) (n = 24)

* Significantly greater than 7'-2''-13' ($p \leq .05$)

+ Significantly greater than BFD ($p \leq .05$)

Figure 1. Skate blade radius of contour (ROC) (lateral view)

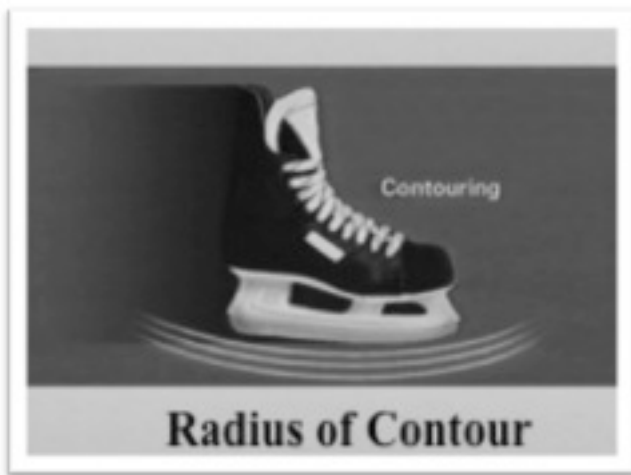


Photo taken from: Lockwood and Winchester (2004)

Figure 2. Skate blade height (lateral view)

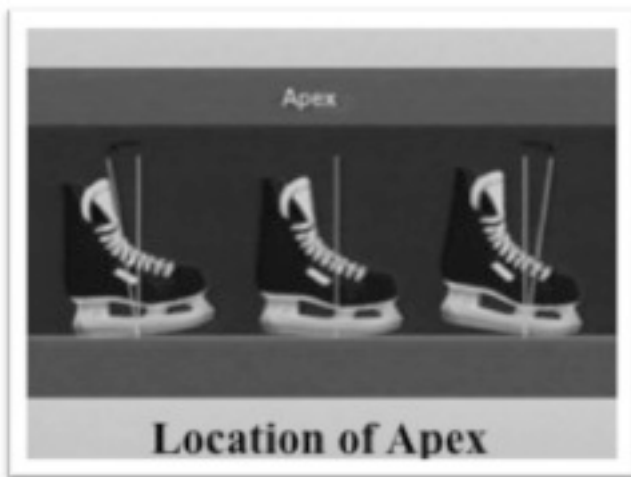


Photo taken from: Lockwood and Winchester (2004)

Figure 3. Skate blade radius of hollow (ROH) (frontal view)

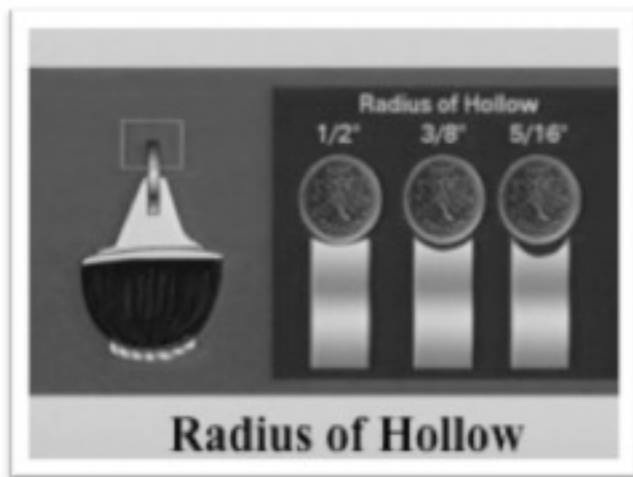


Photo taken from: Lockwood and Winchester (2004)

Figure 4. Skate blade levelness of edges

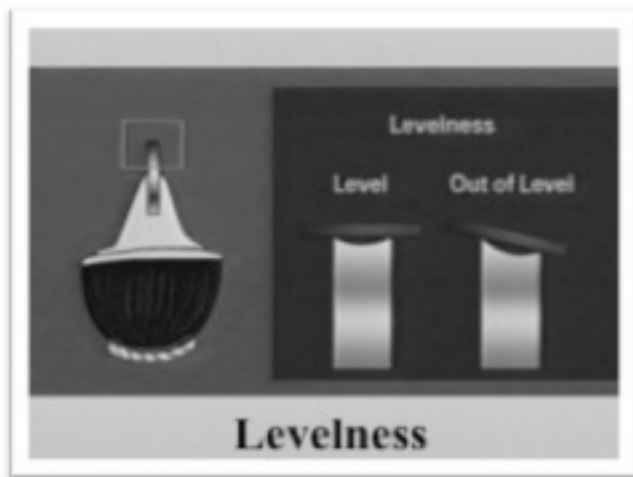


Photo taken from: Lockwood and Winchester (2004)

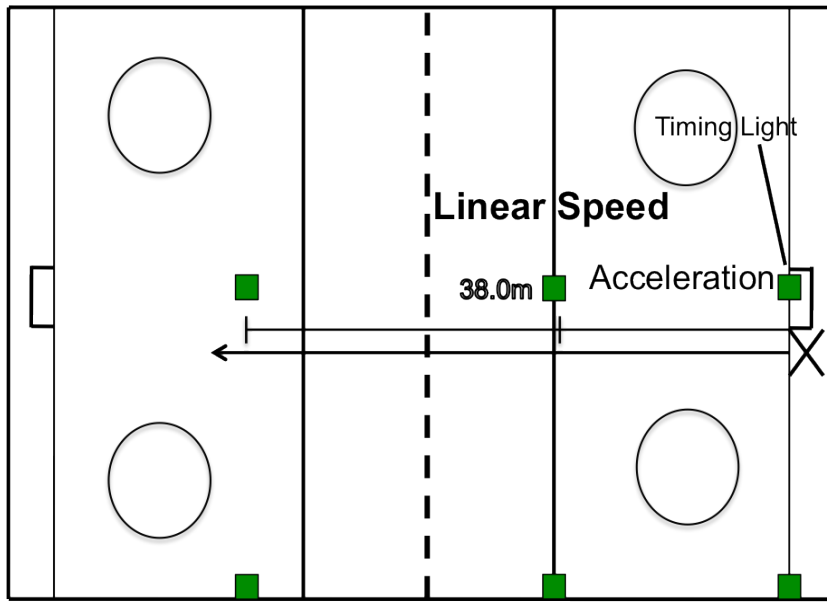


Figure 5. Linear Speed Test set-up

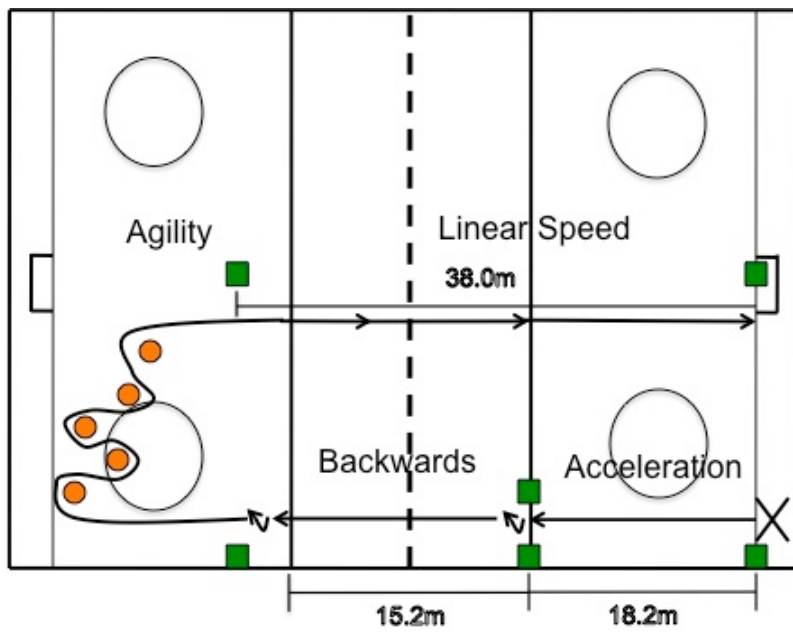


Figure 6. Combination Test set-up

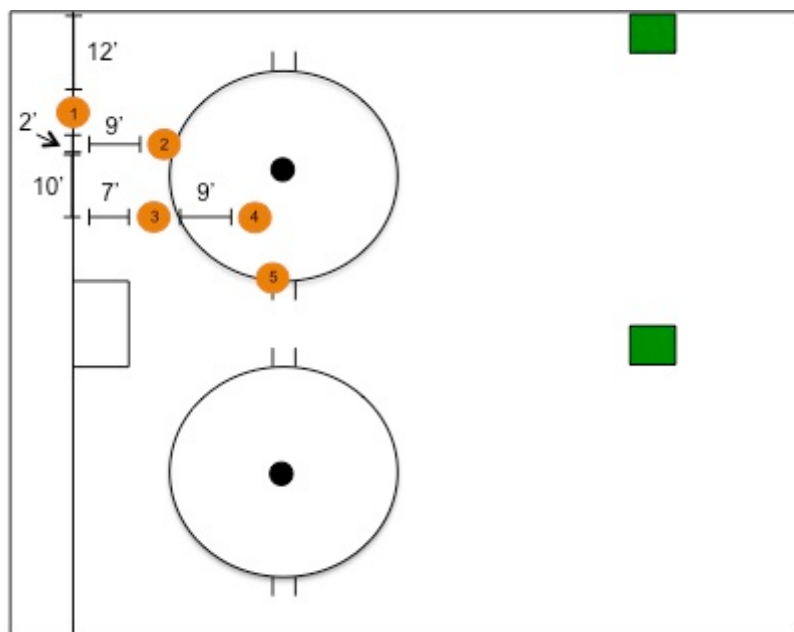


Figure 7. Cone placement for Combination and Agility Tests

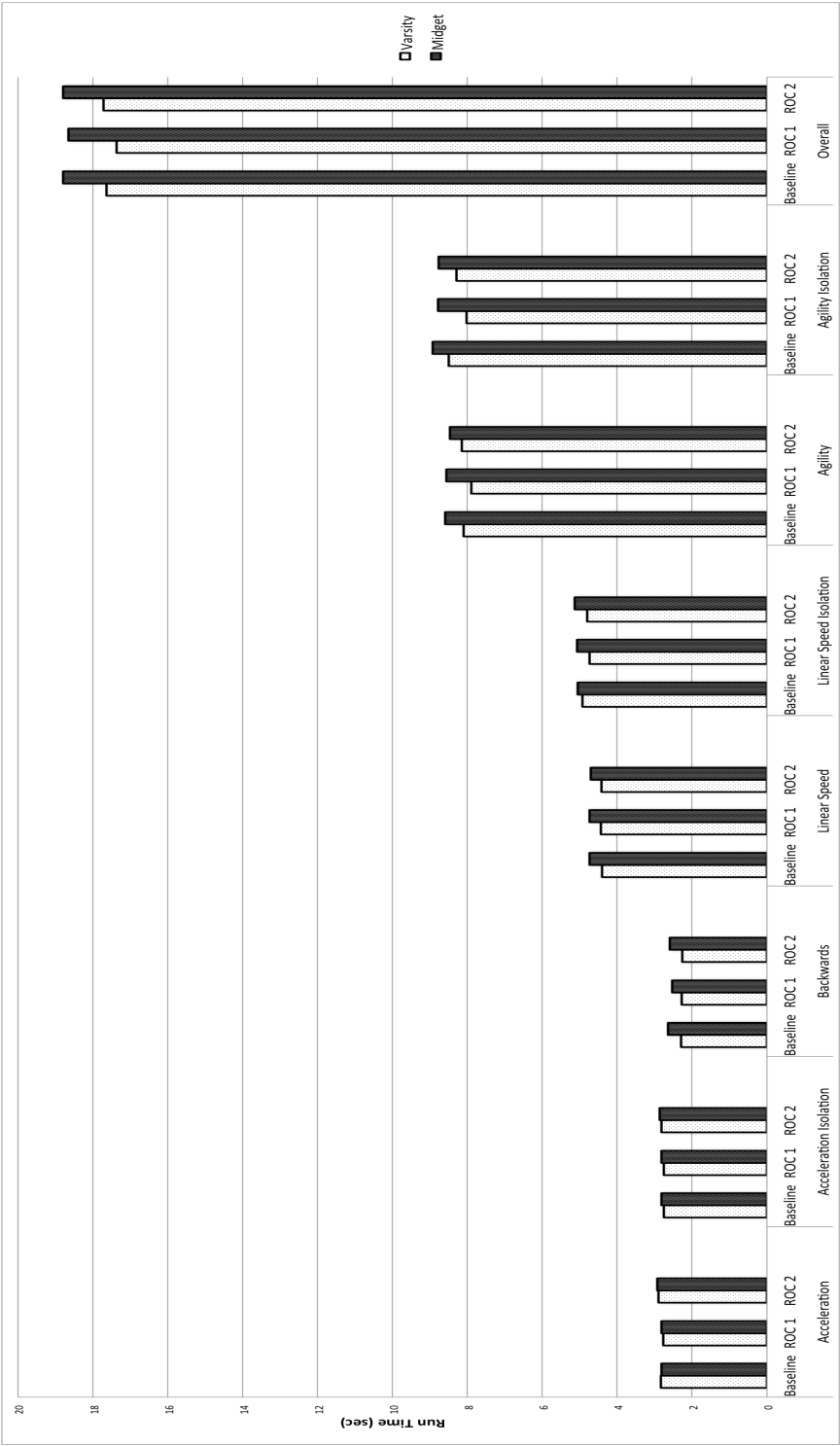


Figure 8. Skating performance times across ROC interventions

(n=24)

ROC 1 = 9'-2"-10'

ROC 2 = 7'-2"-13'

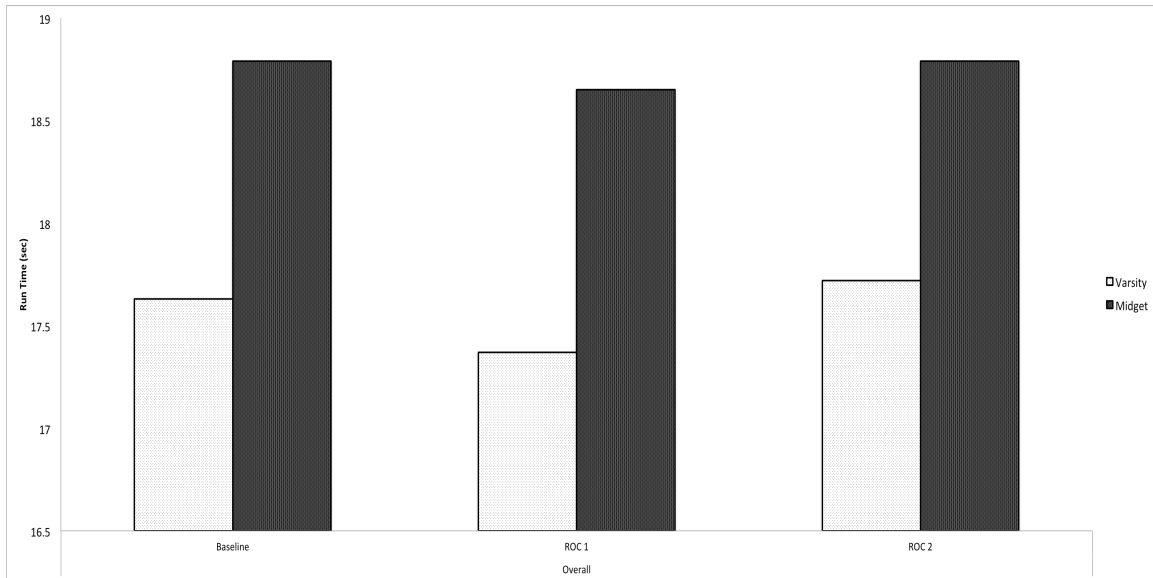


Figure 9. Overall performance times across ROC interventions (n=24)

ROC 1= 9'-2"-10'

ROC 2= 7'-2"-13'

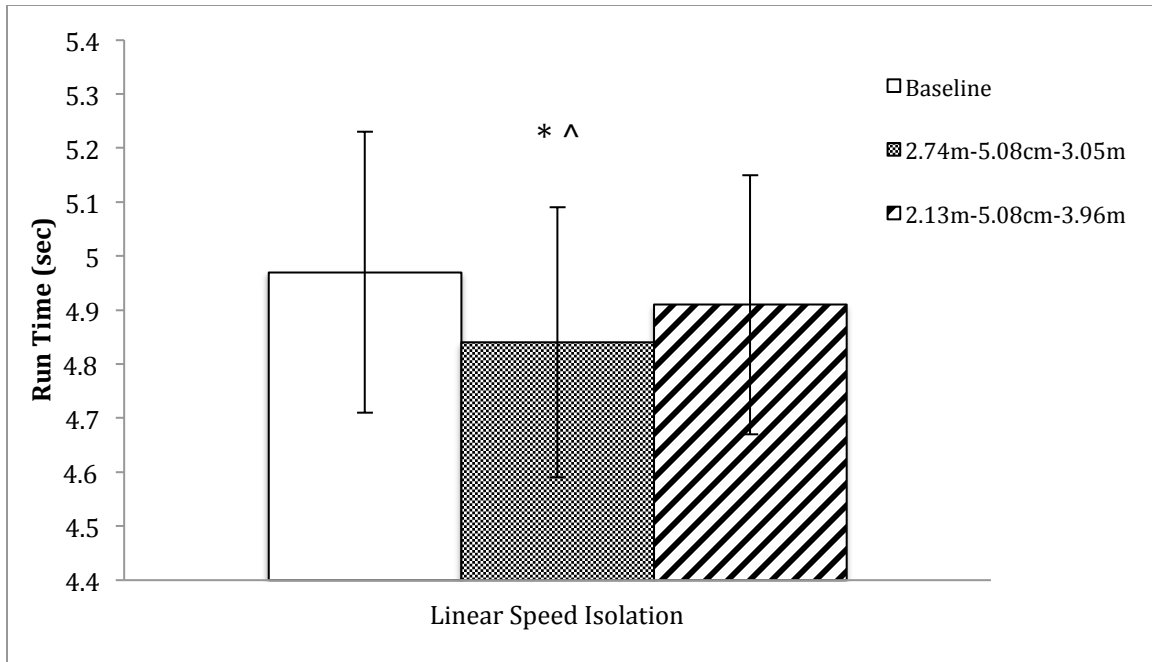


Figure 10. Performance times on LS ISO across ROC interventions
Data represented as mean (SD) (n=24)

* Significantly faster than Baseline ($p < .05$)

^ Significantly faster than 2.13m-5.08cm-3.96m ($p < .05$)

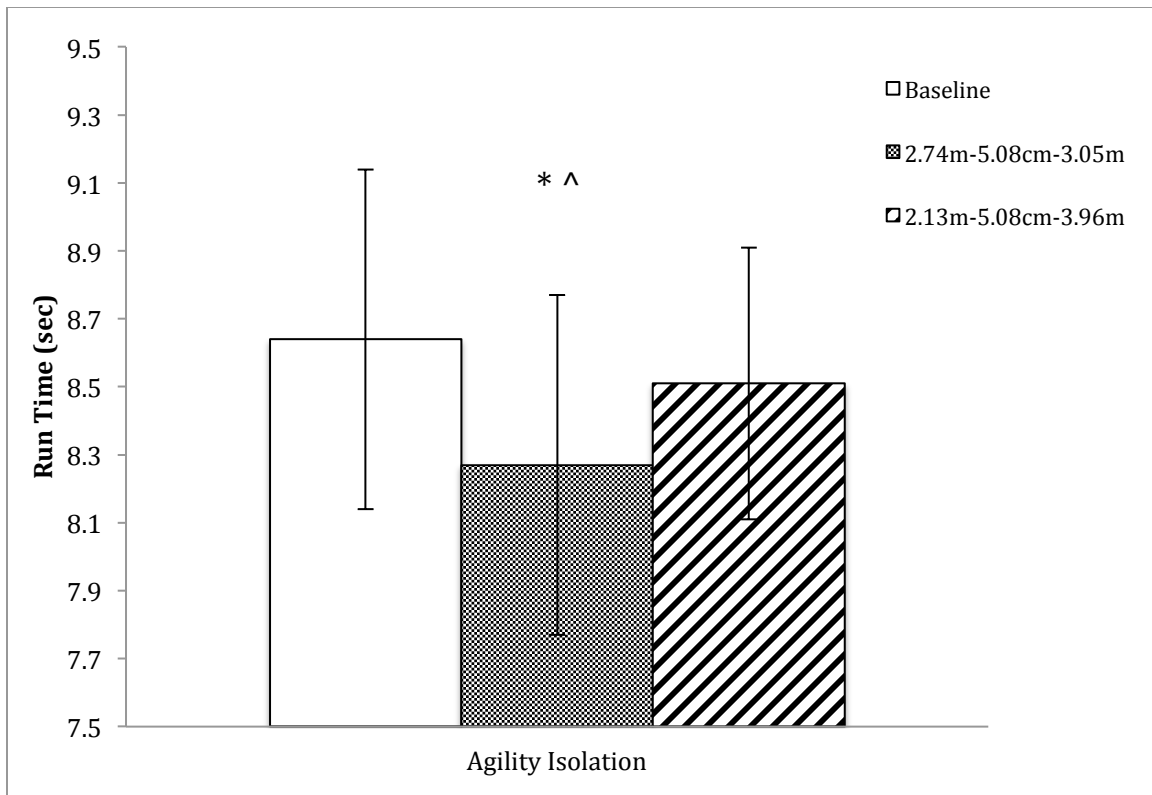


Figure 11. Performance times on AG ISO across ROC interventions
Data represented as mean (SD) (n=24)

* Significantly faster than Baseline ($p < .05$)

^ Significantly faster than 2.13m-5.08cm-3.96m ($p < .05$)

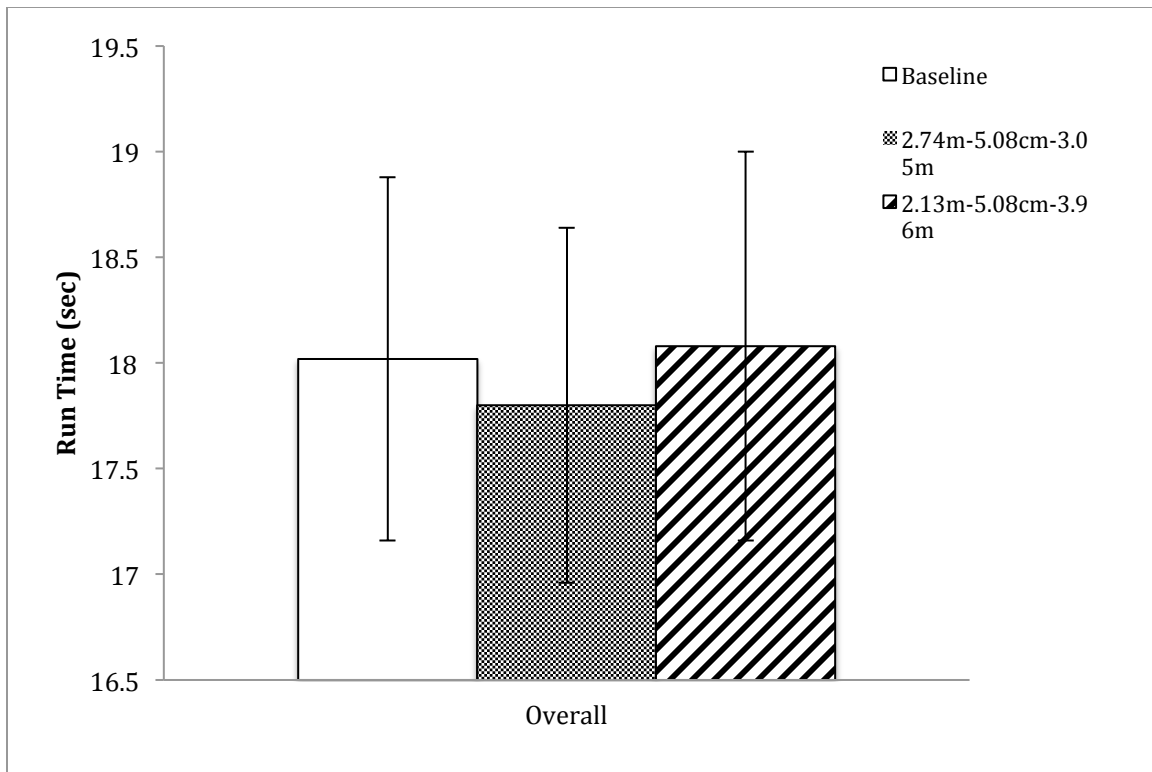


Figure 12. Combination Test performance times across ROC interventions
Data represented as mean (SD) (n=24)

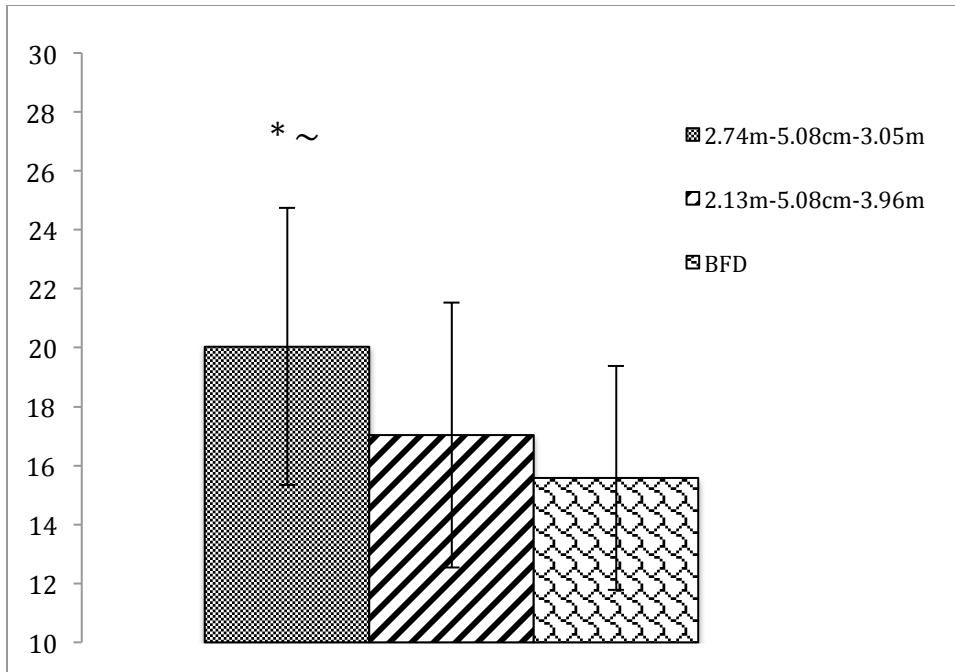


Figure 13. Questionnaire scores across ROC and ROH interventions
Data represented as mean (SD) (n=24)

* Significantly higher than 2.13m-5.08cm-3.96m ($p < .05$)

~ Significantly higher than BFD ($p < .05$)

Glossary of Terms

Grinds: A term used to describe the sharpening that is on the blade of a skate.

ROC: *Radius of Contour.* The lengthwise curvature along the bottom of the skate blade.

This variable impacts the amount of blade that is in contact with the ice. A large radius of contour allows a large amount of blade to be in contact with the ice. A small radius of contour allows a small amount of contact between the blade and ice.

Single ROC: A term used to describe a skate blade that has one contour.

Double ROC: A skate blade that has more than one contour. The apex of the blade is used as the reference point where the two contours meet each other. Typically, a smaller ROC is put onto the front portion of the blade and a larger ROC is put onto the back portion of the blade.

Triple ROC: A skate blade that has two contours and also a flat portion blending the two contours together. The flat portion spans the apex and typically, a smaller ROC is put onto the blade from the flat section forward and a larger ROC is put onto the blade from the flat portion to the back of the blade.

ROH: *Radius of Hollow.* The concave depression running lengthwise along the bottom of the skate blade. This depression creates the inside and outside edges that are necessary on hockey skates. The depth of this depression can be altered during the sharpening process.

Pitch: The pitch is the balance point that is created on the bottom of the skate blade during the sharpening process. The pitch is not always directly in the centre of the skate

blade and it can be moved forwards or back depending on the position and skating habits of the individual player.

Levelness of Edges: This characteristic of sharpening determines if the inside and outside edges created by the ROH are of the same depth. If these edges are not level, the skater can feel as though they cannot grip the ice with their skates.

BFD: *Blademaster Form Dressing*. Similar to the FBV, this change of hollow shape possesses a flat portion between the two edges, however the edges connect at the flat portion with rounded edges.

Appendix A

Participant Request Form

LETTER OF INFORMATION & INFORMED CONSENT

Date: June, 2011

Project Title: VALIDATING THE BLACK ART OF SKATE SHARPENING: The effect of ROC and ROH grinds on on-ice skating speed and agility.

Principal Investigator: Kelly L. Lockwood, Associate Professor

Department of Physical Education & Kinesiology, Brock University

Tel: (905) 688 5550 x3092

Email: kelly.lockwood@brocku.ca

You are being asked to participate in the study titled “VALIDATING THE BLACK ART OF SKATE SHARPENING: The effect of ROC and ROH grinds on on-ice skating speed and agility. The study will be conducted by Dr. Kelly Lockwood, who oversees the On Ice Performance Laboratory at Brock University.

The purpose of the study is to determine if altering the shape of the skate runner (ROC) and hollows (ROH) can influence skating performance. More specifically, whether ROC and ROH can significantly affect speed versus agility related on-ice skating skills and secondly, to investigate the combined effects of single versus double contours on the same on-ice skating skills.

BACKGROUND

In on-ice sport, significant research and investigation has been dedicated to athlete preparation and performance, namely in the sport of hockey how to prepare an athlete to skate, shoot, play. What has not received sufficient research attention has been the contribution of equipment to performance, specifically the point of contact between the player and the ice.

There is currently a very limited understanding of ‘why or why not’ to contour skate runners and if there is a significant effect of ROC and ROH on performance. Athletes, parents, coaches and some technicians assume this process has been completed when blade runners are installed in blade holders on the boots. Unfortunately, the inconsistencies in manufacturing and installing blades does not provide us with the confidence to suggest that the left is the same as the right and furthermore, does not take into the account any further individualization by player or transfer to on-ice performance capabilities. Ultimately, this process will assist in further development of the sport, best practices within skate sharpening and recommendations proposed for athletes at all levels

of play. Outcomes will provide both the industry and the hockey community with a foundation of information upon which coach/player education can be derived. From a commercial or retail perspective, this process will provide evidence for contouring and thus provide the skate sharpeners with empirical information to further develop and support their industrial practices.

OBJECTIVE OF THE STUDY

Preliminary outcomes of the study will provide an initial look at the effect of blade shape or ROC and ROH on skating performance or more specifically, speed and/or agility as two of the primary on-ice skating skills in performance in the sport of ice hockey. As well, the benefits of flat-bottomed grinds versus regular ROH grinds on the same skating performance variables.

WHAT IS INVOLVED?

As a participant, you will be asked to complete the following battery of on-ice performance tests. You will be asked to complete these tests multiple times, once with each of the selected blade sharpening profiles. The tests will be conducted following a standardized warm up and familiarization session to ensure that you are comfortable on the intervention blade sharpening. To ensure the ice conditions do not inhibit skating performance, ice condition will be monitored. Drills will be moved to new sheets of ice or ice resurfacing will be completed on a routine basis and reported. Ice temperature will

also be monitored on an hourly basis to provide further understanding of the variables effecting blade ice interaction. Verbal encouragement will be provided to all players during all tests.

Participation in each testing session will take approximately 20 minutes. A minimum of 24 hours will be scheduled between testing sessions to limit the effects of fatigue and trials will be scheduled at approximately the same time of day to limit the effect of diurnal variation. Each subject will be asked to complete multiple trials lasting 20 minute per sessions. Subjects will maintain their normal practice and game schedule however asked to refrain from any extra physical activity outside of their normal routine.

Below is a description of the on ice skating tests:

Combination Test: This test was originally named the Sabre Skate Test used by the professional teams during conditioning camps. We have modified it slightly for our purposes. It consists of four sections; acceleration (ACC), backwards (B), agility (AG), and linear speed (LS). The ACC section is defined as the time taken to travel from the goal line to the blue line, a distance of 19.5 meters. This distance is sufficient to assess rate of acceleration from a static position. Skaters start in a two-foot stance perpendicular to the direction of travel, with the lead foot on the goal line. Players will skate as fast as possible through the blue line and into the B section. The B section requires to skater to

change orientation at the blue line to backwards and travel backwards 18.0 meters. After 18.0 meters, the skater will change orientation and continue in their original direction and enter the AG section of the test. The AG section has five pylons placed between the goal line, top of the face-off circle and hash marks on the same side of the ice surface. The AG section requires the skater to perform repeated tight turns in both directions to maneuver around the pylons and complete the section. Upon completion, the skater proceeds into the LS or final section of the test. LS requires the skater to skate in a straight line to the original goal line where they started the test traveling a distance of 38.0 meters. The time taken to complete each individual section will be recorded as well as the total time taken to complete the entire test (Time to Completion; TTC) using a Tag Heuer™ HL610 photo-electric timing system (la Chaux-De-Fonds, Switzerland).

Linear Speed Test: This test consists of a 38.0 meter sprint from goal line into the far end zone as fast as possible to assess linear speed. Players will start in a two-foot stance, facing perpendicular to the direction of travel with their lead foot slightly behind to goal line. Upon cue, players will begin at their own discretion and skate as fast as possible from one goal line to the other. The time taken to complete the 38.0 meter sprint will be recorded using a Tag Heuer™ HL610 photo-electric timing system (la Chaux-De-Fonds, Switzerland).

On-ice Agility Test: This test consists of a five pylon agility path, as completed above in the Combination test. The test will begin with the skater standing at the blue line facing

the end zone on the same side as the test setup. Players will start in a two-foot stance, facing perpendicular to the direction of travel with their lead foot slightly behind to blue line. When ready, the subject will skate as fast as possible through the five pylons. The time taken to complete the agility test will be recorded using a Tag Heuer™ HL610 photo-electric timing system (la Chaux-De-Fonds, Switzerland).

Qualitative Feedback: Immediately following each blade sharpening trial, participants will be given a short questionnaire to provide feedback on how the change in blade sharpening affected their ability to skate. Skaters will be asked to respond on a 5-point Likert scale to questions that address how the intervention affected speed, agility, cornering ability, etc. associated with participation in this study.

RISK AND BENEFITS

Although it is not possible to predict all possible risks or discomforts that a participant may experience during a research study involving human activity, the intensity of the activities included in the above described study are not considered to be any more strenuous than a game of ice hockey. It will be the responsibility of the athlete to come to each session prepared to exert physical effort. This includes adequate fuel, hydration, rest and an enthusiastic attitude. Participation in this study may potentially enhance the athlete's understanding of blade sharpening and the effect of blade sharpening on performance.

PUBLICATION OF RESULTS

Upon completion of the study, the industrial partner will receive a final report from which the outcomes will be used for development of technology and best practices in skate sharpening. Scientific results of this study may be published in professional journals and presented at conferences. Feedback about this study will be available by contacting Dr. Kelly Lockwood.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please contact the Principal Investigator using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University (10-085).

If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 Ext. 3035, reb@brocku.ca. Thank you for your assistance in this project. Please keep a copy of this form for your records.

PARTICIPANTS CONSENT

In order to participate in the described study, this documentation must be read and signed.

If participants are 18 years of age and older, they may complete the documentation themselves. If participants are not 18 years of age, the participant consent must be accompanied by parental/guardian consent as outlined below. Completed informed consents are mandatory for participation.

For Participants to complete:

- In signing this form, I _____ (*Participant's Name*),
acknowledge that, I have received an explanation about the nature of the study and its
purpose. I give my permission _____ (*Participant's Name*) to
participate in the research described above conducted by Dr. Kelly L. Lockwood.
 1. Participants can withdraw from the program at any time, without prejudice. An
open door policy with regard to athletes/parents asking questions about the study
and participation will be maintained in confidence.
 2. Although we have strict policies in place to protect all participants in the program,
accidents do happen. I understand that the instructors are qualified and will act in
the best interest of the athletes.
 3. Participant's names and data will be confidential. All skate runners will be coded
so that the sharpener and testers do not know the treadmill given to the individual
subjects.

4. Participants will receive a copy of the Informed Consent Form and their own individual results upon completion of the project.

Participant's Name: _____ **Participant's Signature:** _____

Date: _____

Appendix B

Participant Questionnaire

TESTING SESSION:

PLAYER NAME: _____

Please circle your answer to the following questions on a scale of 1 to 5.

1= strongly disagree

2= slightly disagree

3= not sure

4= slightly agree

TOTAL: _____

5= strongly agree

1. I felt that my skates allowed me to turn better this session compared to my normal sharpening.

1 2 3 4 5

2. I felt that my skates allowed me to go faster this session compared to my normal sharpening.

1 2 3 4 5

3. I felt that my skates glided across the ice better this session compared to my normal sharpening.

1 2 3 4 5

4. I felt that my skates had a stronger grip on the ice this session compared my normal sharpening.

1 2 3 4 5

5. I felt that my skates allowed me to skate faster backwards this session compared my normal sharpening.

1 2 3 4 5

6. I prefer how my skates felt this session compared to my normal sharpening.

1 2 3 4 5